Faster processing of moving compared to flashed bars in awake macaque V1 provides a neural correlate of the flash lag illusion

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This document describes the structure of the deposited data associated with the above study in Journal of Neurophysiology. For updates, please visit the website of Andreas Tolias (https://toliaslab.org).

Overview

The data (all in MATLAB's ".mat" format) are divided into raw and processed. The raw data contain the all the relevant experimental parameters, receptive field data and the individual trial spike trains of single and multiunits. The processed data contain certain key experimental parameters and the trial-averaged mean firing rate (PSTH) aligned to the time when the stimulus appeared at the receptive field center; latencies computed from PSTH and from population decoding are also included. Overall, the data are organized by monkey subjects. Psychophysics data are not included. Details of the individual MATLAB files are as follows.

Raw data

There are four sub-folders, one for each monkey (A, CH, CL and L). Inside them, you will find 'main_exp' (all monkeys) and 'control' (A & CL) subfolders. These contain 'sess_*.mat' files where * refers to session number. Loading this file in MATLAB workspace brings 'rdata' which contains the following fields and subfields. Note that pixel locations are in screen coordinates where (0,0) is the top left corner of the monitor; x-coordinate increases from left to right and y-coordinate increases from top to bottom. Pixel distances can be easily converted to visual angle using the pix_per_deg parameter (see below).

- subject_name – monkey name
- const_params – parameters that are constant for the given session
    - monitor_type – 'LCD' or 'CRT'
    - fix_spot_color – uint8 RGB triplet of fixation spot color
    - fix_spot_size – fixation spot width in pixels
    - fix_spot_location – fixation spot location in pixels in screen coordinates.
    - monitor_size_x – length of monitor screen in cm.
    - monitor_size_y – height of monitor screen in cm.
    - monitor_distance – distance (cm) of monitor center from monkey's eyes.
    - monitor_center_x – horizontal component of monitor center in pixels
    - monitor_center_y – vertical component of monitor center in pixels
    - bar_size_x – width of bar stimulus in pixels
    - bar_size_y – height of bar stimulus in pixels
    - stim_center_x – ARFC (see the Methods in paper) horizontal coordinate in pixels
    - stim_center_y – ARFC vertical coordinate in pixels
    - trajectory_length – motion trajectory length in pixels
    - num_flash_locs – number of flashes (see gray rectangles in Fig. 4B)

- vertical_distance – vertical center-to-center distance in pixels between bar stimuli in control experiment.
- max_stimulus_time – maximum stimulus presentation duration (ms) in a trial
- inter_stimulus_time – gap (ms) between stimuli presented within a trial
- post_stimulus_time – fixation time (ms) after the last stimulus in a trial
- combined – Boolean indicating if this is the main (0) or control experiment (1)
- resolution_x – horizontal monitor resolution in pixels
- resolution_y– vertical monitor resolution in pixels
- refresh_period – monitor refresh period (ms)
- pix_per_deg – pixels per degree of visual angle (e.g. 73) – use this to convert pixel distance to visual angle in degrees. For example, bar width of 20 pixels = 20/73 = 0.274 degrees.

- cond – structure array of stimulus conditions. For example, if there were 7 possible flash location and 3 speeds & 2 directions of motion, there will be 7+3*2 = 13 conditions.
  - cond_idx – a number assigned to each condition; can be used to retrieve trials meeting specific stimulus conditions.
  - is_flash – Boolean indicating if the stimulus is a flash (1) or not (0)
  - is_moving – Boolean indicating if the stimulus is a moving bar (1) or not (0)
  - flash_location – location index (integer) where the flash is presented (see Fig.3A)
  - bar_color_r – uint8 value for red
  - bar_color_g – uint8 value for green
  - bar_color_b – uint8 value for blue
  - direction – motion direction; 0-bar moves from left to right; 1 – right to left. For flash it is set to -1.
  - dx – horizontal center-to-center distance (pixels) between adjacent locations of moving bar. For example, dx = 5 indicates that the bar moves 5 pixels every monitor refresh period. Moving bar speed can be obtained from this by
  - $$speed = 1000 \times dx \times \left(\frac{1}{refresh\ period}\right) \times \left(\frac{1}{pix\_per\_deg}\right)$$
  - arrangement – applies to control experiment ('combined'=true); irrelevant when 'combined' is false (i.e., main experiment). Value of 0 indicates that the moving bar passed through the receptive fields (RF) while the flash was presented outside the receptive fields; value of 1 indicates vice versa, i.e., flash in RF and moving bar outside the RF.
- subtrials – multiple stimuli were presentation within a single fixation period (trial); each of these stimulus presentations therefore forms a 'subtrial', with the following parameters.
  - cond_idx – condition index specifying a unique stimulus. Using the 'cond' structure above, you can get more information about what type of stimulus this is.
  - trial_num – trial number
  - subtrial_num – subtrial number
  - substim_on – stimulus onset time (uint64) in milli seconds. When more than one stimulus is presented in a subtrial of control experiment, onset time is for the moving stimulus.
  - substim_off– stimulus offset time (uint64) in milli seconds. When more than one stimulus is presented in a subtrial of control experiment, offset time is for the moving stimulus.

    - bar_centers - [x;y] screen coordinates (pixels) of moving bar centers; can be empty if only flash was presented in a subtrial.
    - flash_centers – [x;y] screen coordinates (pixels) of flashed bar center; can be empty when only moving bar was presented.
    - spike_data – spike times data for the subtrial
        - multi_unit – data for multiunit
            - unit_id – id for the multiunit
            - spike_times - spike times (ms) aligned to stimulus onset; times restricted to 300 ms before stimulus onset and 300 ms after stimulus offset. Note that you may see spikes reliably at the beginning of the 300 ms segment before stimulus onset; these spikes mostly come from the tail of responses to flashes in the previous subtrial.
        - single_unit – data for single unit, if exists
            - unit_id
            - spike_times
- internal – primary key details internal to Andreas Tolias lab datajoint database.
- receptive_field – white noise based receptive field (RF) data
    - const_params – parameters constant for the mapping session
        - bg_color – uint8 RGB triplet of monitor background color
        - fix_spot_color – uint8 RGB triplet of fixation spot color
        - fix_spot_location – fixation spot location in pixels in screen coordinates
        - fix_spot_size – fixation spot width in pixels
        - dot_color – [a, b] – where a is grayscale index value of dark dot and b is the grayscale index value of bright spot.
        - dot_size – size of dot in pixels
        - stim_frames – stimulus duration in number of refresh periods the dot stimulus stays on. For example, if the refresh period is 10ms, stim_frames of 3 indicates a stimulus duration of 30 ms
        - stim_center_x – horizontal screen coordinate of the dot grid center
        - stim_center_y – vertical screen coordinate of the dot grid center
        - dot_num_x- number of dots in the dot grid in the horizontal dimension
        - dot_num_y - number of dots in the dot grid in the vertical dimension
    - map_axis_x – x-coordinates of the dot centers of the dot grid; to convert this to visual space, subtract stim_center_x from map_axis_x and then use pix_per_deg param to convert the pixel distances to degrees.
    - map_axis_y - y-coordinates of the dot centers of the dot grid
    - multi_unit – receptive field kernels data for multiunits
        - unit_id – id of unit
        - rf_cen – x(azimuth) and y(elevation) coordinates (deg) of receptive field center based on 2d Gaussian fit as explained in the paper.
        - map_data – rf kernel info for the different map types
            - map_type – ‘Bright’ or ‘Dark’ – indicates of the map was obtained using bright or dark dots respectively.
            - lag – reverse correlation lag (ms) of the map
            - map – receptive field kernel

- single_unit – receptive field kernel data for single units, when available.

As an example, you can use the following MATLAB code to plot spike raster for a couple of multiunits from monkey A for a flash stimulus:

```
%% Navigate to data/raw_data/A/main_exp
load('sess_01.mat')
%%
flash3_cond = [rdata.cond.flash_location]==3;
flash3_cond_idx = rdata.cond(flash3_cond).cond_idx;
sb_cond = [rdata.subtrials.cond_idx]==flash3_cond_idx;
% Select trials with flash location 3 as stimulus
sst = rdata.subtrials(sb_cond);
% Plot spike trains for a couple of multiunits
p = 0;
for iUnit = [1 18]
    p = p+1;
    subplot(1,2,p)
    for iTrial = 1:length(sst)
        stimes = sst(iTrial).spike_data.multi_unit(iUnit).spike_times;
        plot(stimes,iTrial*ones(size(stimes)),'k.')
        hold on
    end
end
```

Processed data

These data files contain PSTH and latencies extracted from the raw data. The file 'main_data.mat' contain data related to Figures 5-11. The files 'decoded_data_*.mat' contain population decoding data presented in Figures 12-14. The details of each file are given below:

- **main_data.mat** – loading this in MATLAB workspace will bring 'pdata' with the following fields and subfields.
  - main – data related Figures 5-10
    - subject – monkey subject
    - internal – defined as before
    - T – monitor refresh period (ms)
    - pix_per_deg - pixels per degree of visual angle
    - lum – structure array with data for each bar luminance value
      - lum_val – luminance of bar in cd/m^2
      - flash – data for flash
        - t – bin center times (ms) relative to flash onset
        - mfr – trial-averaged mean firing rate (Hz), dim: [# of elements in t]-by-[number of multiunits]
        - lat – peak response latency (ms)
        - boot – bootstrapped latency values from which error bars were calculated
      - mov – data for moving bar
        - t – bin center times (ms) relative to moving bar arrival time at receptive field center

        - speed – data for individual speed
            - speed_val – speed in deg/s
            - t0 – time (relative to moving bar stimulus onset) at which moving bar hit the receptive field center; dim: [# of neurons]-by-[2 motion directions, left to right and right to left respectively]
            - mfr - trial-averaged mean firing rate (Hz), dim: [# of elements in t]-by-[number of multiunits]-by-[2 motion directions]
            - lat – peak response latency (ms); dim: 1-by-[2 motion directions]
        - boot – bootstrapped latency values; dim: [2 motion directions]-by-2000

- control – data related Figure 11
    - subject, T, pix_per_deg, speed_val and internal – all same as above.
    - single – data where a flash or a moving bar was presented in isolation just like in the main experiment.
        - flash – flash data
            - t, mfr, lat and boot – same as above in 'flash' subfield of 'lum' field.
        - mov – moving bar data
            - t, mfr, lat and boot – same as above in 'mov' subfield of 'lum' field.
    - comb – data where flash and moving bar were presented in the same subtrial
        - flash – data when flash was presented in the receptive field and moving bar outside the receptive field
            - t – bin center times (ms) relative to flash onset
            - loc – data when the flash was at different locations. Some locations may not have any data as no RF fell within those flash locations
                - bar_cen_x – azimuth (deg) of bar center
                - mfr– trial-averaged mean firing rate (Hz), dim: [# of elements in t]-by-[2 motion directions]-by-[# of multiunits]
                - sel_unit_ind – indices of multiunits that were selected to have RF centers within the current flash's width. Indices refer to the order of multiunits used under 'single' field.
                - lat – flash response peak latency (ms); dim: 1-by-[2 motion directions; remember, the moving bar was present when the flash was shown]
                - boot – bootstrapped latency values; dim: 2000-by-[2 motion directions]

- mov – data when the moving bar passed through receptive fields while a flash was shown at different spatial offsets outside the receptive field
    - t – time (ms) relative to moving bar stimulus onset. Note that time segments were padded on both ends of the actual stimulus trajectory times for analysis purposes.
    - mov_cen_x – azimuth (deg) of moving bar centers. Note that extrapolated moving bar centers were padded on both ends matching the above 't' field; dim: [# of elements in t]-by-[2 motion directions]
    - loc – data when bar moved in two different directions while flashes were presented at different locations
        - mfr – trial-averaged mean firing rate (Hz), dim: [# of elements in t]-by-[# of multiunits]-by-[2 motion directions]
        - flash_cen_x – azimuth (deg) of flash center
        - is_traj – Boolean vector indicating which part of the above 't' and 'mov_cen_x' is the actual motion trajectory.
        - lat – motion response peak latency (ms); dim: 1-by-[2 motion directions]
        - boot – bootstrapped latency values; dim: 2000-by-[2 motion directions]

- **decoded_data_(unit_type)_(monkey).mat** – population decoding data of a given unit_type (su-single unit; mu- multiunit) for different monkeys. Loading this file into MATLAB workspace brings 'ddata' with the following fields and subfields:
    - subject – monkey name
    - unit_type – single or multiunit
    - sess – session-wise data
        - internal – as defined before
        - bar_loc_x_deg – azimuth (deg) of flash centers
        - bar_loc_x_deg_i – azimth (deg) of bar centers interpolated for analysis purpose
        - lum – data for different bar luminance conditions
            - flash – flash decoding data
                - bin_end_times – flash response bin end times (ms) relative to flash onset.
                - trial_spike_count_flash_test – trial-by-trial binned spike counts for testing during decoding of flash responses; dim: [# of units]-by-[# of elements in bin_end_times]-by-[# of elements in bar_loc_x_deg]-by-[# of trials].
                - mean_spike_count_flash_train – trial-averaged mean spike count for training the decoder for decoding flashes; dim: [# of units]-by-[# of elements in bin_end_times]-by-[# of elements in bar_loc_x_deg_i]-by-[# of trials]. This is the lambda parameter in Eq.1 in the paper.

- mean_spike_count_flash_train_forMov - trial-averaged mean spike count for training the decoder for decoding moving bar; dim: [# of units]-by-[# of elements in bin_end_times]-by-[# of elements in bar_loc_x_deg_i]. This is the lambda parameter in Eq.1 in the paper.
- p - posterior probability - $p(S \mid \mathbf{R})$ as given in Eq.5 in the paper; dim: [# of elements in flash bin_end_times]-by-[# of elements in bar_loc_x_deg_i]-by-[# of elements in bar_loc_x_deg]-by-[# of trials]

- mov – moving bar decoding data
  - speed – data for different speeds
    - speed_val – speed in deg/s
    - dir – data for each motion direction
      - bin_end_times – mov response bin end times (ms) relative to stimulus onset
      - trial_spike_count_mov - trial-by-trial binned spike counts for testing during decoding of moving bar responses; dim: [# of units]-by-# of elements in bin_end_times]-by-[# of trials].
      - subtraj – info of part of the trajectory overlapping flashed region
        - loc_deg – azimuth of moving bar centers
        - t – time (ms) relative to stimulus onset
      - fulltraj – info of the entire motion trajectory
        - loc_deg, t – as for subtraj
      - p - posterior probability - $p(S \mid \mathbf{R})$ as given in Eq.5 in the paper; dim: [# of elements in mov bin_end_times]-by-[# of elements in bar_loc_x_deg_i]-by-[# of trials]
    -

- aligned –the data presented in panels C, E & F of Fig 12-14 – where the posterior probability is aligned in some way to the stimulus location.
  - lum – data for different luminance values
    - flash
      - p – trial- and session-averaged posterior probability restricted to the width of the flash; dim: [# of elements in sess.lum.flash.bin_end_times]-by-[# of flash locations]
      - lat – latency (ms) of maximum of posterior probability
    - mov
      - loc_deg_aligned – spatial bin centers relative to the instantaneous position of motion trajectory (this is the abscissa of panel E of Fig. 12-14).

- p_sess_avg_spacealigned – posterior probability corresponding to the loc_deg_aligned above (this is the ordinate of panel E in Fig. 12-14).
- lat – latency (ms) of maximum of p_sess_avg_spacealigned (ordinate in panel F in Fig. 12-14).
- spatial_lag – distance of peak of peak of p_sess_avg_spacealigned from origin.

- sess_avg – posterior probability averaged over trials and sessions – the data here are what are plotted in panels B & D of Fig.12-14.
  - lum – data for different luminance values
    - flash
      - p – posterior probability; dim: [# of elements of sess.lum.flash.bin_end_times]-by-[# of elements in sess.bar_loc_x_deg_i]-by-[# of flash locations]
    - mov
      - speed
        - dir – motion direction
          - p – posterior probability; dim: [# of elements of sess.lum.mov.speed.dir.bin_end_times]-by-[# of elements in sess.bar_loc_x_deg_i]
- boot – used for obtaining error bars in Fig.12-14.
  - flash – flash latencies bootstrapped as described in the paper
  - mov – moving bar latencies bootstrapped; dim: [# of speeds]-by-[2 motion directions]-by-[# of luminance vals]-by-2000.